

Why you need to use ground control points (GCP) for drone mapping

by Eric van Rees



Measuring GCP with Emlid Reach RX

Ground control points (GCPs) are physical markers on the ground with known coordinates. These points are essential in drone mapping as they improve the georeferencing accuracy of aerial images, ensuring that maps and models align with real-world coordinates. GCPs are critical for industries such as construction, surveying, and environmental monitoring, where precision is key.

This article clarifies GCPs role, answering common questions like: do I need GCPs even with an RTK setup? How many should I use? How to place and collect them? Read on to understand why GCPs can still be essential, even with advanced drones, and learn best practices for integrating them effectively.

How do GCPs work in drone mapping?

GCPs work by providing known coordinates that help align the images captured by a drone with real-world coordinates. During the mapping process, the position of each GCP is recorded using high-precision GNSS equipment. After the drone flight, these GCPs are identified in the aerial images, and the mapping software uses their positions to correct distortions and errors in the imagery.

How do GCPs enhance accuracy in different drone mapping workflows?

When it comes to drone mapping, there are two main workflows to consider:

1. *Drone mapping with regular (non-RTK GPS) drones.* This workflow relies heavily on GCPs because of the lower accuracy of standalone GNSS systems installed on regular drones, which typically result in positional errors of 1–2 meters. GCPs correct these errors during post-processing to enhance the accuracy of the aerial maps. This method was common before the widespread adoption of RTK drones.
2. *RTK/PPK drone mapping.* RTK (Real-Time Kinematic) and PPK (Post-Processing Kinematic) drone mapping offer more precise positioning, reducing errors to a few centimeters. While RTK drones can significantly reduce the need for GCPs, they still benefit from GCPs in large or complex environments where maximum accuracy is required.

Do you need GCPs with RTK drones?

A common question is whether GCPs are necessary when using an RTK drone. The answer is yes, GCPs are still recommended, especially in large or uneven areas. Although RTK drones provide real-time, high-precision positioning, GCPs act as an extra layer of quality control, ensuring that even minor positional

deviations are corrected. GCPs become even more critical when mapping areas with complex topography or when the highest accuracy is essential, such as topographic mapping or construction site planning.

How to identify and mark ground control points?

GCPs appear in various forms, including the following:

- Painted marks on the ground, including circles, the letter “X,” squares, and checkerboard patterns;
- Metal or plastic survey disks and plates, that are fixed to the ground;
- Metal or wooden survey stakes or pins, that are driven into the ground;
- Natural features such as boulders or the corner of a field.

GCPs should be marked properly so they are clearly visible in the field and in the drone imagery.

Bright and high-contrast colors such as white, yellow, and fluorescent colors are good choices, to differ from the surroundings as much as possible. The materials used for GCPs should be durable, for example, metal discs, stakes, or fabric targets. See in the BOX some creative examples of GCPs from Emlid users.

How many GCPs are needed for drone mapping?

The number of GCPs required for a drone mapping project depends on various factors, including the size of the site, terrain complexity, and the desired level of accuracy. The ideal number of GCPs for most drone mapping projects is between 5 and 10, according to the tests conducted by

the Nevada Department of Transportation. More GCPs do not significantly improve accuracy beyond this range, and the time investment in placing extra GCPs may not yield substantial benefits.

Key considerations include:

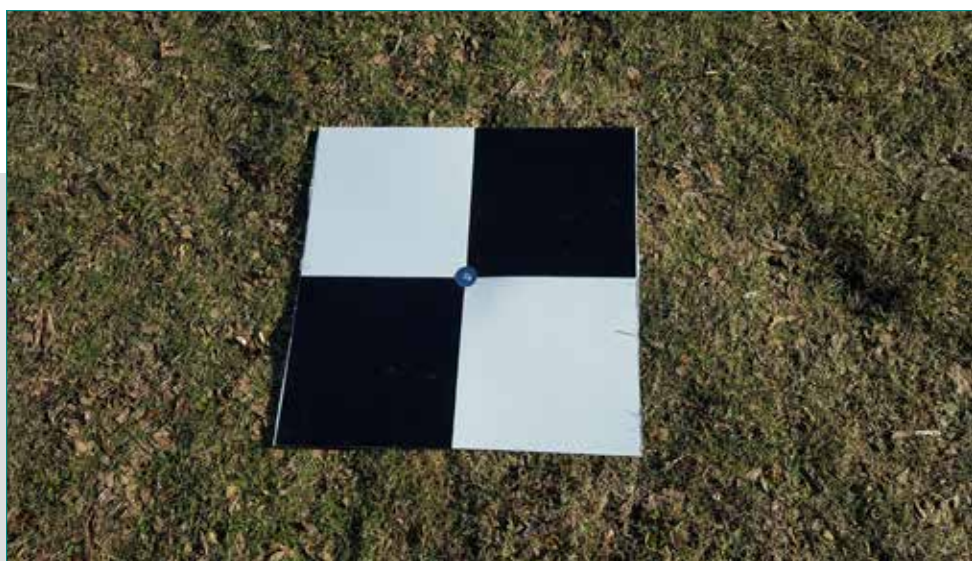
- Project area size: For smaller, less complex areas, fewer GCPs may be sufficient. More GCPs will be needed to cover the site adequately for larger areas or projects requiring high precision.
- Terrain complexity: If the landscape has significant variations in elevation or rugged terrain, additional GCPs might be required to account for distortions in the mapping data.
- Accuracy requirements: For projects demanding high accuracy, more GCPs will ensure that the entire site is accurately georeferenced. Lower accuracy projects may require fewer GCPs.

Where should GCPs be placed?

Placing Ground Control Points (GCPs) for a drone mapping project requires careful planning to ensure accurate results.

While uniform placement of GCPs across the entire area might seem ideal, it's often not practical or necessary in real-life scenarios. Instead, GCP placement should be adapted to the project's needs and terrain characteristics. Here's how to approach it:

- Strategic placement: GCPs should be distributed strategically, rather than uniformly, across the area to capture both horizontal and vertical variations. It's crucial to cover areas with significant elevation changes to minimize distortions and ensure accurate georeferencing.
- Avoid boundary distortions by placing GCPs correctly: While GCPs should be placed near the corners of the project area, ensure the coverage extends beyond the area of interest. This prevents mapping distortions that can occur when critical points fall outside the GCP boundaries. Expanding the coverage beyond the immediate site ensures accuracy across the entire mapped area, including the edges.
- Elevation consideration: In areas with significant elevation differences, place GCPs at both



The key rule is to use high-contrast colors for GCP to ensure they are easily visible from the drone. This is why GCPs are often designed in black and white

the highest and lowest points to account for vertical accuracy. This helps correct potential distortions caused by elevation changes during data processing. Stable and visible locations: GCPs should be placed on stable ground and positioned in areas that are not easily disturbed. Avoid placing GCPs in spots where they could be obstructed by vegetation, shadows, or other barriers that could affect visibility in drone imagery.

For detailed guidance on GCP placement, including the entire workflow from setup to post-processing, watch Emlid's in-depth webinar and tutorial.

How are ground control points collected?

After placing a GCP, its position needs to be measured with an RTK or PPK-capable GNSS receiver. Any Emlid Reach device including the Reach RX and Reach RS3 can be used for this task. Due to its compatibility, portability and lightweight, the Reach RX rover suits well for placing and measuring of GCPs, while the Reach RS3 can function as both a base and a rover.

The Reach RX is an ideal GNSS receiver for jobs that require quick, efficient, and precise measurements, such as placing and measuring the position of ground control

points (GCPs). This compact, lightweight rover excels in scenarios where portability, ease of use, and speed are critical.

How are the measured GCPs used during image processing?

A list of all coordinates of different GCPs is stored in a .csv or .txt file, specifying the longitude, latitude, and altitude for each point. That file must be uploaded with the drone imagery to a software platform that stitches all imagery together in a single, orthorectified map of the surveying area.

By identifying the exact pixel locations of GCPs in the images, photogrammetric software can match these points to their known geographic coordinates. This alignment corrects positional errors and distorts, ensuring the drone images accurately reflect real-world locations.

www.youtube.com/emlid

Conclusion

GCPs remain essential even with RTK and PPK drones. While these advanced drones can reduce the number of GCPs needed, they cannot eliminate the need for them entirely, especially for large or complex sites. GCPs act as a safeguard, ensuring the highest possible accuracy for all drone mapping projects.

Whether you're working on a small-scale project or a large industrial site, incorporating GCPs ensures your drone imagery is as accurate as possible, saving time, minimizing errors, and producing reliable results. For most drone mapping projects, the optimal number of GCPs ranges from 5 to 10, as adding more than 10 offers minimal improvement in accuracy. Once a GCP is placed, its location should be measured using a GNSS receiver with RTK or PPK capabilities. Any Emlid Reach device, such as for example Reach RS3, can be used for this purpose.

Learn more about how to enhance your RTK workflows with Emlid's high-precision receivers and software here: <https://emlid.com/drone-mapping/>.

FAQ

How to use ground control points for drone mapping?

Ground Control Points (GCPs) are used to correct for positional errors of drone imagery and match them with their real-world positions. After flying a drone to map the area in which the GCPs are placed, the known position of the GCPs are correlated with the captured drone imagery using specialized software to enhance spatial accuracy.

How do we collect ground control points (GCPs)?

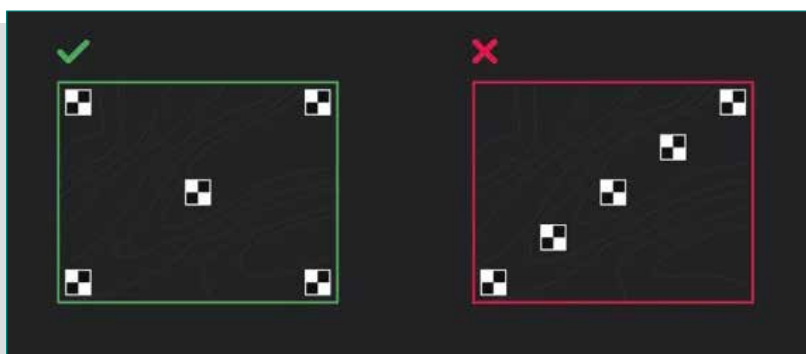
GCPs are recorded by placing highly visible markers at known coordinates throughout the survey area. These coordinates are precisely measured using GPS or total station equipment. During drone flights, GCPs are captured in the imagery.

Do you need ground control points with RTK?

Yes, it is recommended to use ground control points in combination with RTK for quality control and error correction in aerial surveys.

What is a GCP on a map?

A GCP on a map is a distinct and easily identifiable location for which the ground coordinates are known. A GCP can be a marked point on the ground, but also a natural or man-made object on a well-noticeable spot.



Try to place GCPs at the highest and lowest points on the site. It will help perform the correct flat projection.

Creative examples of GCPs



Credits: All images by the "Show us your Ground Control Point targets - Share your experience in the Emlid User community". (<https://community.emlid.com/t/show-us-your-ground-control-point-targets-share-your-experience/13039>)

REFERENCES

<https://blog.emlid.com/how-to-place-ground-control-points-tutorial-by-emlid/>
<https://blog.emlid.com/more-than-six-thousand-points-over-four-days-interview-with-emlid-user/>
<https://blog.emlid.com/precise-drone-mapping-with-emlid-gear-setup-gnss-base-station-gcps-and-more/>

KEYWORDS

GCP; DRONE MAPPING; GROUND CONTROL POINT; PHOTOGRAMMETRY;

ABSTRACT

The article explains why Ground Control Points (GCPs) remain essential in drone mapping, even with the advent of RTK/PPK drones. GCPs act as reliable reference markers that correct positional errors, ensuring that aerial imagery aligns accurately with real-world coordinates. The text outlines how to design and place GCPs, how many are typically needed (usually 5–10), and how they are integrated into photogrammetry software. By providing best practices and practical tips, the article highlights how GCPs serve as a critical layer of quality control, guaranteeing accurate and dependable results for applications in construction, surveying, and environmental monitoring.

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ArcGIS Platform

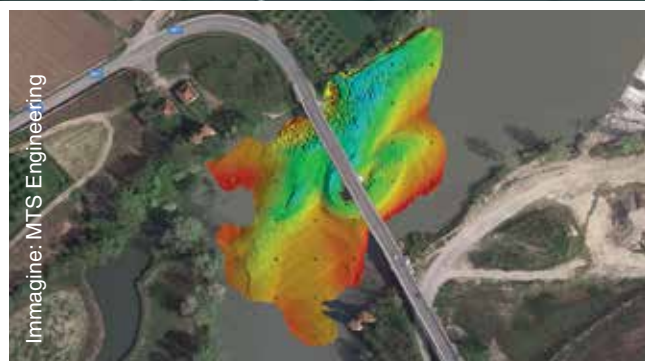
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